Absence, Substitutability and Productivity: Evidence from Teachers

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February 3, 2022

Abstract

Teacher absence is a widespread phenomenon, but little is known about its effects on teacher productivity and schools' strategies to cope with this temporary disruptive event through substitute teachers. Using a unique French administrative dataset matching, for each absence spell, each missing secondary school teacher to her substitute teacher, I find that, on average, teacher absence reduces pupil test scores by around 0.40 % of a standard deviation. On average, substitute teachers are unable to mitigate this negative effect. However, there is substantial heterogeneity depending on the type of substitute teacher: certified substitute teachers are able to compensate for up to 25 % of this negative impact, while non-certified substitute teachers have no statistically significant effect. **JEL**: I2, J2, M51. **Keywords**: absence, substitutability, productivity, teachers.

1 Introduction

Teacher absence is a widespread phenomenon in many developed countries. On a typical school day in the United Kingdom, the United States, and France, three to

*Contact: a.benhenda@ucl.ac.uk. I am deeply grateful to Julien Grenet, Thomas Piketty, Roland Rathelot and Gill Wyness for guidance and support. Part of this paper was conceived during my visit at Columbia University, I am grateful to Jonah Rockoff for very insightful feedback. I also thank seminar participants at UCL, Paris School of Economics, and UC Berkeley for helpful comments. I also thank the French Ministry of Education for help with the data. I acknowledge financial support from the Alliance Program of Columbia University.

six percent of teachers are absent (Griffith, 2017). Despite the importance of this phenomenon, empirical evidence on the causal effect of teacher absence on productivity is scarce.[1] Even less is known about the potential mitigating impact of substitute teachers. When a teacher is absent, how does it hurt her productivity? How easily can substitute teachers mitigate this effect?

I offer an empirical answer to these questions using a comprehensive administrative French panel dataset covering the 2007-2015 period, and matching, for each absence spell, each missing secondary school teacher to her substitute teacher. This paper estimates, for Math, French and History ninth grade teachers and their pupils: a) the effect of the number of non-replaced days on pupil test scores; b) how this impact can be mitigated by the assignment of substitute teachers; c) how the impact of substitute teachers depends on their quality, measured by their certification status (certified versus non-certified teachers).

The main empirical challenge is the endogeneity of teacher absence and substitution. Existing literature suggests that teacher absence is correlated with observed and unobserved teacher and pupil characteristics (Ost and Schiman, 2017). I implement a two-way fixed effect model with teacher and classroom fixed effects to address this empirical challenge. This model exploits the longitudinal dimension of the data with teacher-school fixed effects. It also exploits the cross-sectional dimension of the data: in secondary school, teachers are subject-specific, and pupils stay with the same peers in the same classroom throughout the school year and for all subjects. This allows me to use variations within classroom, across subject. I perform several robustness checks to confirm that the results are not driven by a) reverse causality: teachers are more absent when assigned to low performing pupils, and it is more difficult to find substitute teachers for these pupils; b) the fact that absences are only a reflection of poor on-the-job teacher productivity.

Based on the analysis of more than 100,000 teachers and three million pupils, I show that teacher absence has a statistically significant negative impact on pupil test scores: one additional day of absence reduces pupil test scores by 0.03 % of a standard deviation. This is consistent with previous causal estimates in developed countries (Clotfelter et al., 2009; Herrmann and Rockoff, 2012). As teachers miss an average of 13 days per year, the average effect of their absence is to reduce pupil test scores by around 0.40 % of a standard deviation. The fraction of replaced absence days does not have any statistically significant compensating effect. However, one additional replaced

[1] To my best knowledge, there are only four papers on this question: Miller et al (2008); Clotfelter et al. (2009); Duflo et al. (2012); Herrmann and Rockoff (2012)

day with a certified substitute teacher (as opposed to a missed day at school) mitigates 26 % of the marginal impact of non-replaced days. The marginal impact of a replaced day with a non-certified substitute teacher (as opposed to a missed day at school) is not statistically significant.

I also estimate heterogeneity by teacher and absence spell characteristics to give suggestive evidence on the underlying mechanisms highlighted in a conceptual framework. I begin by estimating heterogeneity by length of absence spell. One of the predictions of the conceptual framework is that the longer the absence spell, the more pupils or their parents can adjust and put in place alternative compensating strategies such as private tutoring. I observe that the marginal impact of one additional day of non-replaced absence decreases with the length of the absence spell. This suggests that one long absence spell is less harmful to pupils than multiple shorter absence spells. I then turn to the role of the gap in general human capital between the regular and the substitute teachers. The main prediction from the conceptual framework is that the larger this gap, the smaller the mitigating effect of substitution. I use teacher experience as a measure of general human capital because the link between teacher experience and teacher productivity is well established in the literature (see Koedel et al., 2015 for a review). I find that the mitigating effect of certified substitution is not significantly impacted by the experience gap. This suggests that the results cannot be entirely explained by this mechanism. Next, I investigate the role of the specific human capital gap: teaching requires specific human capital that can be acquired only through prolonged and repeated interactions with pupils. First, I perform a heterogeneity analysis by month of the school year. I do not find that substitute teachers have a smaller compensating impact at the end of the school year, when the gap in specific human capital between the absent and the substitute teacher is the largest. Second, I compare planned absences with unplanned absences: with planned absence, absent teachers have the opportunity, prior to their absence, to reduce the gap in specific human capital with their substitute teachers by sharing content with them and giving them guidelines. I find that planned absences are slightly less disruptive for pupils. Thus, overall, evidence on the importance of this mechanism is mixed.

This paper makes several key contributions to several strands of the literature. First, my paper combines teacher fixed effects with classroom fixed effects to further deal with the endogeneity of teacher absence and substitution. Classroom fixed effects further address the issue of reverse causality. This is an advancement on previous literature on the causal effect of teacher absence on productivity (Miller et al.,2008; Clotfelter et al., 2009; Duflo et al., 2012; Herrmann and Rockoff, 2012) which to date

has only relied on teacher fixed effects.

Second, my paper provides an in-depth analysis of teacher substitution. I analyse whether absence spells are actually covered by a substitute teacher and, if so, by whom. Most previous papers on the causal effect on teacher absence do not analyse substitute teachers. Only Clotfelter et al.(2009) analyse substitute teachers, and they only compare the marginal effect of the number of absences covered by a certified substitute teacher to the marginal effect of the number of absences covered by a non-certified substitute teacher. I am able to identify the marginal effect of non-replaced and replaced days, irrespective of the type of substitute, where the counterfactual is a missed day of class. Given the important administrative and budgetary cost of substitute teachers, identifying the impact of non-replaced and replaced days is relevant for policy makers regardless of the substitute teachers' certification status. From this perspective, my paper also contributes to the literature on instruction time (Pischke, 2007; Lavy, 2015). This literature finds that longer instructional time has a positive impact on pupil test scores and one-time grade progression. While these papers focus on variations in planned instruction time defined by law, I analyse how pupil achievement is affected by variations in the number of hours of instruction caused by non-replaced days of teacher absence.

Furthermore, I show that non-certified substitute teachers have no statistically significant impact on pupil test scores in the French context, where the certification process is very demanding and has low passing rates. This is an advancement on Clotfelter et al. (2009), who analyse the role of substitute teachers' certification in the US context, where teacher certification is neither selective nor competitive (Koedel, 2011) and where existing evidence suggests that teacher certification is, at best, a weak predictor of teacher quality. While my results only apply to substitute teachers, they still provide suggestive evidence that a demanding and selective certification process may contribute to better teacher screening. This is consistent with the emerging literature on effective teacher screening (e.g., Jacob et al., 2018).

Third, I perform several heterogeneity analyses by substitute teacher characteristics and absence spell characteristics, which allows me to explore some potential mechanisms underlying the impact of teacher absence on pupil achievement. I am able to test several hypotheses with respect to teacher substitutability, and the role of specific human capital. Existing evidence on worker substitutability and the role of specific human capital focuses on non-educational settings (Hensvik and Rosenqvist, 2016; Jager and Heining, 2019; Grinza and Rycx, 2020). Teaching is particularly appropriate for the analysis of the relationship between human capital specificity (pupil-specific,

grade-specific etc., see Ost, 2014) and substitutability because it is a complex, multidimensional task, based on direct, personal and prolonged interactions with the "output" (pupils).

The remainder of this paper is organised as follows. Section 2 describes the French educational context. Section 3 presents a highly stylised conceptual framework to illustrate the mechanisms through which teacher absence and substitution affect pupil outcomes. Section 4 presents the data and descriptive statistics. Section 5 describes the empirical strategy, section 6 the baseline results, and section 7 the robustness checks. Section 8 details the heterogeneity analysis. Section 9 discusses the main policy implications of the baseline results. Section 10 concludes.

2 Institutional Setting

To provide context for the empirical analysis, this section describes the main relevant features of the French educational system. I present the different types of teachers and the teacher assignment system.

2.1 Secondary School Teachers in France

The public French educational system is highly centralised. The French territory [2] is decomposed in 25 large regions, called *académies* (hereafter regions). Schools have little autonomy, and they are all required to follow the same national curriculum. Headteachers cannot hire nor fire their teachers.

Secondary school teachers are selected through a subject-specific national competitive examination. This examination is academically demanding and has low passing rates (between 15 and 30 %). There are two main certification levels: basic, called CAPES (*Certificat d'aptitude au professorat de l'enseignement du second degré*) and advanced, called *Agrégation*. Conditional on passing this examination, teachers become civil servants and are managed by the central government. Certified teachers have a permanent position and cannot be fired.

Certified teachers are assigned via a centralised point-based system (called SIAM, *Système d'information et d'aide aux mutations*) with two rounds: the inter-regional round and the regional round. Candidates submit a rank-ordered list of choices and are assigned according to a modified version of the school-proposing Deferred Acceptance mechanism (Combe, Tercieux and Terrier, 2021). Teachers' priorities are mostly

[2] This paper focuses on mainland France and does not analyse its overseas territories.

determined by their number of years of experience. Every year, i) new teachers and certified teachers who want to change region apply to the inter-regional mobility round; ii) participants of the inter-regional mobility round, and certified teachers who want to change school within their region, apply to the intra-regional mobility round.

Teachers' wage is set through a national wage scale based on teachers' number of years of experience and certification level (none, basic and advanced). For example, the gross wage of a teacher with the basic certification level and a year of experience is approximately 2,000 € per month. Wages do not vary across schools and do not depend on teacher output.

Secondary school teachers are subject-specific: each subject is taught by a different teacher. The legal working week is 15 hours for teachers with an advanced certification level and 18 hours for teachers with a basic certification level. There is no tracking by major nor ability. Pupils stay in the same class, with the same peers throughout the school year and in all subjects. For ninth graders, a typical week consists in 29 school hours, distributed across 11 teachers-subjects, among which 4 hours of French, 3.30 hours of Mathematics, and 3.30 hours of History.[3] At the end of 9th grade, pupils take a national and externally graded examination called *Diplôme national du Brevet* in three subjects: French, Math and History. This exam takes place in the very last days of June /early days of July.

2.2 Teacher Absence Leave Regulation

There is no limit in the number of days of paid absence each teacher can take per year. Teachers are fully paid during the first three months of their absence leave for minor illness, and during the first year of their leave for serious illness. After this period, they receive half of their regular pay. Maternity leave lasts from 16 to 46 weeks and is fully paid. Paternity leave lasts from 11 to 18 days and is also fully paid. Teachers can also take fully paid leaves for professional reasons such as training, meetings, participation to an examination board *etc.*.

2.3 Teacher Substitution Procedure

Teacher absences are not systematically replaced in France. Overall, the probability of replacement depends on the length of the absence spell and the availability of substitute teachers. Absences are handled by the regional educational authority (*rectorat*). There

[3]The rest of the hours are distributed between Foreign Languages (5h30), Science (4h30), Sport(3h) and Art (2h), see http://www.education.gouv.fr/cid80/les-horaires-par-cycle-au-college.html

are no official precise criteria: regional educational authorities are simply asked to give priority to long-term absences (IGEN, 2011).

In practice, when a teacher is absent, she must notify her headteacher, who then notifies the region via an online form, irrespective of the length of the absence spell. Regional educational authorities assign substitute teachers manually.

When no substitute teacher is found, pupils must stay inside the school building during their missed instruction hours. They usually stay in study rooms and are supervised by hall monitors (*surveillants*). Hall monitors are young adults (usually university students working part-time) who supervise pupils at school when they are not in class, e.g., when they are in schools' study rooms, corridors, cafeteria, etc.[4]

2.4 Substitute Teachers

Certified Substitute Teachers. Certified teachers can ask to become substitute teachers during the intra-regional mobility round of the centralized teacher assignment procedure but most certified substitutes (*Titulaires sur zone de remplacement*) are teachers who applied to the inter-regional mobility round and failed to obtain one of their choices in the intra-regional mobility round (IGAENR, 2015). They are assigned to a reference school called *établissement de rattachement administratif* (RAD), and are called to replace absent teachers in any school located in a geographical area called *zone de remplacement*.[5] There are around 250 *zones de remplacement* in France. Certified substitute teachers' wages do not depend on the number of substitution spells they perform nor on the number of hours they work. Their wage is fixed and equal to the regular certified teachers' wage. As explained above, there is no clear rule for the assignment of certified substitute teachers. Regional educational authorities are in charge of the assignment and do it manually. They are only given the general guideline to give priority to long absence spells (IGEN, 2011). Substitute teachers do not have the option to refuse an assignment. [6]

Non-certified Substitute Teachers. When there is a shortage of available certified substitute teachers, regions hire non-certified teachers on the spot. Non-certified teachers are hired through a separate system. Candidates apply directly to regional

[4]The French government introduced in 2005 a new regulation to encourage internal substitution. Official guidelines stated that short absences can be handled directly by headteachers, who can ask her teachers to substitute for colleagues. However, subsequent policy reports show that this policy was extremely unpopular among teachers and was therefore never implemented by headteachers (IGEN, 2011; Cour des comptes, 2017).

[5]Décret 99-823 du 17 septembre 1999

[6]This is different in other countries such as the United States, see Gershenson (2012)

educational authorities via an online platform.[7] They must hold at least a Bachelor's degree and have no criminal record to be eligible to teach in secondary school. Candidates submit their resume, cover letter and, in some regions, their geographical preferences. Regional professional inspectors manage the selection process. In general, professional inspectors are experienced teachers. They screen candidates based on their online application and conduct interviews. Successful candidates are hired on a short-term contract (*Contrat à durée déterminée*) of maximum a year. Non-certified teachers' wage depends on their degree (Bachelor's, Master's or more), their professional experience, and on their region.[8] For example, the gross wage of a non-certified teacher in Paris, with a Bachelor's degree and a year of experience is 1699 € per month. Non-certified teachers who want to become certified teachers must pass the certification examination.

3 Conceptual Framework

This section presents the main intuitions and predictions of a highly stylised conceptual framework illustrating how teacher absence can impact teacher productivity and how this impact can be mitigated by substitute teachers. The detailed conceptual framework is presented in Appendix A.

This framework builds on the education production function framework. Teacher productivity depends on her ability, general human capital (including professional experience) and, importantly, pupil-specific human capital. The basic intuition of pupil-specific human capital is that the more teachers spend time with their pupils, the better they are at teaching them. This may be because they get to know pupils and adjust to their idiosyncrasies and have more time to implement a long-term instructional strategy. Existing suggestive empirical evidence backs this intuition. Duflo, Dupas and Kremer (2011) suggest teachers adjust their teaching style in response to changes in class composition. Herrmann and Rockoff (2012) find daily productivity losses from absence decline with the length of an absence spell, consistent with substitute teachers learning on the job. The main predictions of this conceptual framework are as follows. Teacher absence can impact teacher productivity through different channels, depending on whether the absent teacher is replaced, and on the quality of the substitute teacher:

[7] This online platform is called, depending on the region, either SIATEN (Système d'information des agents temporaires de l'Éducation nationale) or ACLOE (Application de gestion des candidatures en ligne)

[8] Source: http://vocationenseignant.fr/devenir-enseignant-contractuel-ou-vacataire-mode-d-emploi

1. If the regular teacher is absent and no substitute teacher is assigned, the main channels are the loss of instruction time and the amount of pupil-specific capital the regular teacher loses during her absence:
   - the longer the absence spell, the more pupils or their parents can adjust and put in place alternative compensating strategies such as private tutoring;
   - the higher the regular teacher productivity (both general and specific human capital), the bigger the impact of the absence spell on pupils.
2. If the regular teacher is absent and a substitute teacher is assigned, the main channels are:
   - the difference in ability and experience between the regular and the substitute teachers;
   - how fast substitute teachers gain pupil-specific human capital;
   - the amount of pupil-specific capital the regular teacher loses during her absence.

4 Data and Descriptive Statistics

In this section, I present the administrative data on teachers, absences and pupils. The main advantage of the data is that it is a comprehensive panel matching each teacher to her pupils, as well as each absent teacher to her substitute teacher for each absence spell. The main estimation sample is composed of all ninth grade pupils and their Math, French, and History teachers from 2007 to 2015. This corresponds to approximately 100,000 teachers and three million pupils. I present descriptive statistics on the distribution of absence and substitution spells across teachers and schools. I also present a correlational analysis of the relationship between teacher and school characteristics, and absences/substitution.

4.1 Data

This paper relies on administrative data from the French Ministry of Education covering the whole country from school years 2006-2007 to 2014-2015. I focus on Math, French and History teachers matched to their ninth grade pupils. A detailed description of the data can be found in Appendix B. I use four datasets:

- individual data on pupils including an encrypted national identification number, gender, financial aid status, parents' occupation as well as the identification number of their school and of their classroom. A separate database includes their test scores at the end of 9th grade examination in French, Math and History. I standardise these test scores by year and region.
- individual data on teachers including national identification number, date of birth, gender, number of years of teaching experience, teaching subject, assignment identification number, school identification number and classroom identification number. I use the school identification and classroom identification numbers to match each teacher to her pupils. I only take into account absence days occurring during open business days and remove holidays and weekends.
- data on teacher absence spells: regional identification number of the absent teacher as well as day, month and year of their absence spells, detailed cause of absence (minor illness, major illness, maternity leave, training etc.) and region identification number.
- data on substitute teachers' assignment spells: day, month and year of their assignment spells, assignment identification number, school identification number. The match between the absent and the substitute teachers is made on their assignment identification numbers.

4.2 Summary Statistics

Distribution of Absence Spells. Each year, 55 percent of teachers do not take any absence leave (Figure 1). Among absent teachers, around half take one absence spell only. The majority of absence spells are health-related: 50 % for minor sickness, 10 % for long term illness, 3 % for maternity leave, 2 % for maternity leave extension (in case of a difficult pregnancy or childbirth) and 1 % for professional illness (Figure 2a). Long term illness and minor sickness represent more than 75 % of absence days (Figure 2b).

Teachers are absent 13.14 days per year on average, which represents around 7 % of annual instructional time. More than 36 % of absence spells last only one day. The distribution of absence spells is right-skewed, with 80 % of absence spells lasting less than 20 days (Figure 3).

Distribution of Substitution Spells. In 2015, the number of replaced days is equal to 10 days per year: around 75 % of absent days are replaced (Figure 4). On average, certified substitute teachers cover 5 days of absence per year. In 2015, pupils

spend 3 % of their annual instructional time with certified substitute teachers, against 6 % in 2007. The share of replaced days with a non-certified substitute teacher is more than four times higher in 2015 than in 2007 (from 10 % to around 45 %).

There are large variations in replacement rates by length of absence spell (Figure 5). On average, only 0.4 % of one day absence spells and 6 % of one week absence spells are replaced. The replacement rate rises quickly with the length of absence spells and reaches 50 % for 20 days absence spells and 90 % for 100 days absence spells. Importantly, the share of replacement spells done by non-certified teachers increases with the length of the absence spells for absence spells lasting less than 20 days (which represent more than 80 % of the absence spells). The share of replacement spells done by non-certified substitute teachers is equal to 6 % for one day absence spells, against more than 17 % for 20 days absence spells.

There are also large variations in replacement rates across regions (Figure 6). In the Creteil region (disadvantaged Eastern suburb of Paris), only 6 % of absence spells are replaced whereas in the Nice region (French Riveria), almost 45 % of absence spells are replaced. The share of absence spells replaced by non-certified substitute teachers also differs greatly between these two regions. In Creteil in 2015, 51 % of replacement spells are done by non-certified substitute teachers, against 33 % of replacement spells in Nice. This point is important because it shows social inequalities in pupils' exposition to non-certified teachers.

Substitute Teacher Characteristics. Non-certified teachers are on average less experienced than regular teachers and certified substitute teachers (Table 1). Non-certified teachers have on average 4.6 years of experience, whereas certified substitute teachers have 10 years of experience and regular teachers 14.1 years. 32 % of non-certified teachers have a year or less of experience, against 13 % of certified substitute teachers and 2 % of regular teachers. For both regular teachers and certified substitute teachers, *Agrégation* recipients represent 5 % of the population and CAPES recipients approximately 75 %. By definition, non-certified teachers do not have any teacher certification. I now try to give suggestive evidence on the quality of non-certified substitute teachers. I focus on the subsample of non-certified substitute teachers who take the same certification examinations as regular teachers and certified substitute teachers while working as non-certified teachers (Table 2). Candidates who are non-certified teachers perform very badly both at *Agrégation* and CAPES. For example, only 16 % of them pass the CAPES against 33 % of candidates who are not non-certified teachers. This result gives suggestive evidence that the quality of non-certified teachers might be lower than certified substitute teachers'.

Relationship between Teacher Characteristics, School Characteristics, and Absences/Substitution. Finally, I analyse the relationship between observable teacher, school and pupil characteristics, and the probability of absence/replacement (Table 3). There are no official specific criteria, except length of absence spell, for the assignment of substitute teachers. As a result, there is a significant heterogeneity in the probability of substitution across subject or school. Compared to French and History, Math teachers are less likely to be replaced (column 3). Math teachers are also more likely to be replaced by a non-certified substitute teacher than French or History teachers (column 5). Additionally, schools with more disadvantaged pupils are less likely to get substitute teachers (column 3). They are also more likely to get non-certified substitute teachers (column 5) and less likely to get certified substitute teachers (column 6).

The correlational analysis in Table 3 is also a first step towards understanding the potential sources of bias in the identification of the causal impact of absence/replacement on pupil achievement. First, I look at the relationship between teacher experience and absences/replacements (columns 1 and 2). The number of absence days increases with teacher experience, even with teacher-school fixed effects. This correlation is consistent with other studies on the determinants of teacher absence (DEPP, 2015; Ost and Schiman, 2017). As most absences are health-related, this relationship may be due to the strong correlation between experience and age: older teachers have a more fragile health than younger ones. The correlation between experience and absences is steeper when teacher fixed effects are included (column 2). It suggests a survival bias: the more dedicated teachers are less likely to be absent, and these teachers are overrepresented at later experience/age levels. The share of replaced days and teacher experience are negatively correlated (columns 3 and 4). This may reflect teacher sorting into schools by experience: inexperienced teachers are more likely to be assigned to schools that have less access to substitute teachers. Second, I look at the role of teacher seniority, defined as the number of consecutive years in the same school (columns 1 and 2). The number of days of absences decreases with seniority, even with teacher-school fixed-effects. A possible explanation might be school-specific human capital: teachers find it difficult to adapt when they move to a new school as it may increase their workload. Less senior absent teachers are more likely to be replaced (columns 3 and 4). This might reflect headteachers' decision-making: they might provide more support to more junior teachers by given them a substitute teacher. Overall, this correlational analysis suggests the importance of controlling for teaching subject, pupil characteristics as well as teacher experience and seniority when analysing teacher absence and replacement.

5 Empirical Strategy

I implement a two-way fixed effect model with teacher-school and classroom fixed effects to identify the impact of absence and substitution on pupil achievement. In this section, I describe the econometric framework for the two-way fixed effect model and discuss the identification assumptions.

5.1 Empirical Strategy

The main empirical challenge is the non-random teacher-pupil matching. Table 3 suggests that teacher absence and substitution can be correlated with observed and unobserved teacher characteristics. These teacher characteristics can have a direct impact on pupil achievement. Column 1 of Table 3 confirms results from the literature showing the statistically significant relationship between teacher experience, her number of days of absence and her pupils' socioeconomic background (e.g. Ost and Schiman, 2017). Additionally, columns 3, 5 and 7 of Table 3 show a statistically significant relationship between teacher substitution and pupil socioeconomic background, keeping experience and other teacher characteristics equal. To deal with these issues, I estimate a two-way fixed effect model with teacher and classroom fixed effects. I exploit the longitudinal dimension of the data with teacher-school fixed effects, which control for both observed and unobserved teacher fixed characteristics (Miller et al., 2008; Herrmann and Rockoff, 2012). In other words, I use within teacher, across years variations in the number of days of absence and replaced days. This source of variation has already been used by previous studies on the impact of teacher absences on pupil achievement (Miller, 2008; Herrmann and Rockoff, 2012). However, unobserved variations in pupil ability, which can impact both teacher absence/replacement and pupil test scores, are a major concern for the validity of a strategy based only on teacher fixed effect. Therefore, I go a step further and leverage the fact that a) teachers are subject-specific, b) pupils stay with the same peers in the same classroom, throughout the school year and in every subject. I use variation within classroom, across subjects. Formally, this model writes:

$$Y_{i,c,s,j,a,t} = A_{j,a,t}\beta + R_{j,a,t}\gamma + \pi_s\eta_t + \theta_c + \kappa_j + X_{i,t}\lambda + Z_{j,t}\mu + e_{i,c,s,j,a,t} \quad (1)$$

where $Y_{i,c,s,j,a,t}$ is the standardised test score of pupil i, in classroom c and subject s, with teacher j, during year t. $A_{j,a,t}$ is the number of work day absences taken by teacher j during the absence spell a in year t and $R_{j,a,t}$ the number of replaced work days during the absence spell a taken by teacher j in year t. I interact subject fixed effects π_s with year fixed effects η_t to control for subject specific confounding factors

that vary across years (such as exam difficulty). Additionally, θ_c is the classroom fixed effect, and κ_j is the teacher-school fixed effect.[9] Finally, $X_{i,t}$ is a vector of pupil characteristics (gender, parental occupation and financial aid status) and $Z_{j,t}$ a vector of teachers' time-varying characteristics, experience and seniority (number of consecutive years spent teaching in the same school). Robust standard errors are clustered by school, which is the most conservative level of clustering. The level of observation is pupil x absence spell x teacher-subject (as teachers are subject specific). This approach is equivalent to giving more weight to pupils who experience more frequent teacher absence. I do not sum the number of absence/ replaced days per teacher-year because that would make the implicit assumption that one long absence spell is equivalent to multiple short absence spells. This is not the case with respect to the probability of replacement: Figure 5 shows that long absence spells are much more likely to be replaced than short term absence spells. This is also consistent with Herrmann and Rockoff (2012) who show that multiple short absence spells are more harmful to pupils than one long absence spell.

I analyse the scope of identifying variation by plotting, after estimating the preferred specification, the relationship between residual variation in absences and residual variation in pupil test scores (Figure 7). Figure 7 shows a clear negative relationship between the residual variation in absences and pupil test scores, which confirms that there is enough scope for identifying variation.

5.2 Identification Assumption and Potential Threats to Identification

The parameters of interests $A_{j,a,t}$ and $R_{j,a,t}$ are identified under the following assumption: variations within teacher, across years and within classroom, across subjects in the number of absence/replaced days are not correlated with variations in unobserved determinants of pupil test scores. These would include i) within teacher variations in productivity, such as experience or motivation; ii) pupil ability or iii) teachers' overall working conditions.

Table 3 shows that experience and seniority (defined as the number of consecutive years spent in the same school) are strongly correlated with the number of days of

[9] I do not include teacher fixed effects and school fixed effects separately because teacher-school fixed effects are more flexible. They do not make any assumption on the impact of teachers switching school on their absence and replacement. Keeping the same identifier for teachers when they switch school makes stronger assumptions on the determinants of their absence and replacement. It assumes that these determinants remain fixed across schools.

absence and replacement (columns 1 to 4). We also know from the literature that experience and seniority are observable determinants of teacher quality. Therefore, I include experience and seniority as control variables. A source of unobservable variations in within teacher quality may be teacher motivation. Existing literature shows that the propensity to be absent can reflect teachers' level of motivation (Jacob, 2013; Gershenson, 2016). If, for example, a teacher is burning out, then her absences can also be a symptom of poor on-the-job productivity. I discuss this point in the robustness checks section with placebo tests in the number of days of absence and replacement. Second, low achieving pupils can discourage teachers and raise absences, i.e., there could be reverse causality. Pupil controls address this bias. The classroom fixed effect also addresses this issue under the assumption that, within classroom, there is no subject specific matching, i.e., that pupils relatively worse in one subject are not systematically assigned to relatively more absent/less replaced teachers. This reverse causality bias is further discussed in the robustness checks section, with a placebo test of the impact of absence/replacement of a teacher in one subject on her pupil test scores in another subject (i.e., with another teacher).

Another type of potential threat for identification is more specific to the replacement parameters. These parameters would not be identified if replaced absence spells were not comparable to non-replaced absence spells. The main determinant of replacement is the length of the absence spell, as suggested by the institutional setting and the descriptive statistics sections. Table 3 also shows that the correlation between the share of replaced days and pupil characteristics becomes statistically insignificant after controlling for teacher-school fixed effects (column 4). The correlation between the type of substitute teacher and pupil characteristics also becomes statistically insignificant once teacher-school fixed effects are included (columns 6 and 8). This gives suggestive evidence of the validity of the identification assumption for the replacement parameters.

Finally, it is important to note that this identification strategy relies on across subject variations in the number of absent/replacement days. The estimated parameters give the average effect across subjects and rely on the assumption of a constant effect across subjects. I relax this assumption in the heterogeneity analysis by subject (section 8.2).

6 Baseline Results

The baseline results show that one additional day of absence reduces pupil test scores by 0.03 % of a standard deviation. On average, the share of replaced days does not

have any statistically significant mitigating effect. This average effect masks substantial heterogeneity: certified substitute teachers can mitigate up to 25 % of this negative effect whereas non-certified teachers have no statistically significant mitigating effect.

6.1 Impact of the Number of Days of Absence and Replacement

I begin by presenting estimates of the impact of absence and replacement on pupil test scores (Table 4). Column 1 reports naive estimates, without fixed effects. With this specification, an additional non-replaced day of absence is associated with a 0.13 % of a standard deviation decrease in pupil test scores. An additional replaced day (compared to missing a day of school) is associated with a 0.06 % of a standard deviation increase of pupil test scores. In other words, replaced days compensate more than 45 % of the negative impact of absence. I now control for teacher-school fixed effects. The effect of absences is divided by three but remains statistically significant (column 2). Including teacher-school fixed reduces the impact of absence, which is consistent with a negative correlation between teacher quality and absences. Furthermore, with this specification (column 2), the effect of replaced days becomes statistically insignificant. This suggests a positive sorting between absent teachers and substitute teachers: the best absent teachers seem more likely to get substitute teachers.

Finally, with the preferred specification (column 3), which also includes classroom fixed effects, one additional day of absence reduces pupil achievement by 0.03 % of a standard deviation. As teachers miss an average of 13 days per year, the average effect of their absence is a reduction in pupil test scores by around 0.40 % of a standard deviation. This is consistent with the literature, which finds that one additional day of absence reduces pupil achievement by 0.06 - 0.17 % of a standard deviation (Miller et al.,2008; Clotfelter et al., 2009; Duflo et al., 2012; Herrmann and Rockoff, 2012). The effect of replaced days remains statistically insignificant, which suggests that the sorting between absent and substitute teachers depends more on teacher characteristics than on pupil characteristics.

6.2 Impact of the Number of Days of Replacement by Type of Substitute Teacher

The above results suggest that substitute teachers are, on average, unable to compensate the negative impact of teacher absences. Table 5 shows that the impact of

replaced days largely depends on the type of substitute teachers. With the preferred specification (column 3), certified substitute teachers can mitigate more than 25 % of the marginal impact of absences. The marginal impact of a replaced day with a non-certified teacher (as compared to missing a day of school) is not statistically significant.

This result suggests that substitute teacher quality plays an important role in the mitigating impact of substitution. It is consistent with the conceptual framework: one of the main mechanisms underlying the impact of teacher absence is the human capital gap between the regular and the substitute teachers. This result is also consistent with Clotfelter et al. (2009) who show, using administrative data from North Carolina, that the marginal effect of an additional absence with a certified substitute teacher is a reduction in reading test scores by 0.06 percent of a standard deviation against 0.10 percent of a standard deviation with a non-certified substitute teacher.

7 Robustness Checks

This section discusses the two main potential threats to identification: reverse causality and absence as a symptom of poor on-the-job teacher quality. I perform several robustness checks and conclude that neither are likely to bias the results.

7.1 Threat I: Reverse Causality

Placebo test with pupils' teacher in another subject. A concern for the validity of the baseline results is the bias caused by unobserved variations in pupil ability, which can impact both teacher absence/replacement and pupil test scores. I test whether the absences/replacements of a teacher in one subject impact her pupil test scores in another subject (i.e. with another teacher) to address this concern. For example, if the baseline results were driven by pupil ability, then the absence days and replaced days of pupil i's Math teacher would be significantly correlated with pupil i's test scores in French. Table 6 reports regression estimates of the effect of absence and replaced days of the "other subject" teacher of pupil i on pupil test scores. Panel A reports the impact of Math teacher absence/replacement, Panel B the impact of French teacher absence/replacement and Panel C the impact of History teacher absence/replacement. For example, column 1 of panel A reports the impact of Math teacher absence on pupil Math test scores, controlling for Math teacher fixed effects. Column 3 of panel A reports the impact of Math teacher absence on pupil French test scores, controlling for Math teacher fixed effects. This table shows that the Math teacher absences and

replacement days are not significantly related to pupil achievement in French and in History. This is also true for the French teacher absences and replacement days on Math and History test scores as well as for the History teacher absence and replacement days on French and Math test scores. Thus, this placebo test gives compelling evidence of the robustness of the baseline results.

7.2 Threat II: Absence as a Symptom of Poor On-the-job Teacher Quality

Previous and Following Year Absences and Substitution. I also test whether teacher absence is only a symptom of poor on-the-job teacher quality. If, for example, the impact of absence was only capturing the fact that absent teacher were slowly burning out, then previous and following years absences would have a statistically significant impact. Table 7 reports a placebo test of the effect of absence and replacement of the previous year $(t-1)$ and following year $(t+1)$ of teacher j on pupil test scores during the year t. This table shows absent days and replacement day of years $t-1$ (columns 1 and 2) and $t+1$ (columns 3 and 4) do not have any statistically significant impact on pupil achievement in year t. Therefore, it does not seem that the results are biased by poor on-the-job teacher performance.

Absences During School Holidays. Teachers who fall sick or pregnant during the school holidays (days when they do not have class) or during the summer can report these days to their school to have these absence days transferred during school time.[10] These absence spells represent around 1 % of the absence spells. Half of them are maternity leaves happening over the summer holidays. By definition, absences during school holidays do not impact pupil instructional time and have no direct disruptive effect on pupils. I leverage these absences to test whether the baseline results are driven by the fact that absence can be a symptom of poor on-the-job teacher quality. If this proposition were true, then absences during school holidays would have a statistically significant impact on pupil test scores. Since absence days during school holidays cannot have a direct impact on pupils, any observed relationship would be due to endogeneity. Table 8 shows regression estimates of the marginal impact of one day of absence during school holidays. These estimates are not statistically significant. Therefore, it suggests that the baseline estimates are not driven by the fact that absence is a symptom of poor on-the-job teacher quality.

[10] Source: https://www.service-public.fr/particuliers/vosdroits/F2481

8 Heterogeneity Analysis

Having established the effect of teacher absence and substitution on pupil achievement, I now assess the heterogeneity of this effect across teachers, absence spells and school characteristics. This heterogeneity analysis sheds light on the underlying mechanisms and gives suggestive evidence on the conceptual framework's predictions.

8.1 Heterogeneity by Length of Absence Spell

One of the predictions of the conceptual framework is that the longer the absence spell, the more pupils or their parents can adapt. They can put in place alternative compensating strategies such as private tutoring. I test this prediction by estimating the marginal impact of one additional day of non-replaced absence by length of absence spell. If the prediction is true, then the disruptive impact of one additional day of non-replaced teacher absence would decrease with the length of absence spell. In other words, the daily productivity losses would decline with the duration of the absence spell.

I observe that the marginal impact of one additional day of non-replaced absence decreases with the length of the absence spell (Figure 8), which is consistent with the previous literature (Herrmann and Rockoff, 2012). One additional non-replaced day of absence reduces pupil achievement by around 0.1 % of a standard deviation for one day absence spells against 0.05 % of a standard deviation for 10 days absence spells. Thus, this result suggests that one long absence spell is less harmful to pupils than several absence spells.

8.2 Heterogeneity by Subject

According to the conceptual framework, loss of instructional time is the main channel through which non-replaced days affect pupil achievement. In this framework, the impact of loss of instructional time increases with the productivity of the absent teacher. I investigate this mechanism by leveraging the research design to estimate heterogeneity across teaching subject. Existing literature shows that teacher productivity varies greatly by subject. Math teachers value-added is higher than in other subjects (see Chetty et al., 2014 for the latest evidence). Thus, according to the conceptual framework, the negative impact of non-replaced days in Math should be higher than in the two other subjects.

Figure 9 reports regression estimates by teaching subject. The marginal impact of

one additional day of non-replaced absence in Math is to reduce pupil achievement by 0.08 % of a standard deviation. In French and History, this impact is equal to 0.04 % of a standard deviation. The fact that absences have a larger impact in Math than in other subjects is consistent with the literature (Miller et al., 2008; Herrmann and Rockoff, 2012). This result is also consistent with the intuition that the higher the teacher value-added, the higher the impact of absence.

8.3 Heterogeneity by the Experience Gap between the Substitute and the Regular Teacher

Another major prediction of the conceptual framework is that the mitigating effect of substitution depends on the general human capital gap between the absent and the substitute teachers. I use teacher experience as a measure of general human capital because the link between teacher experience and teacher productivity is well established in the literature (see Koedel et al., 2015 for a review). According to the conceptual framework, the larger the experience gap between the absent and the substitute teachers, the smaller the mitigating impact of substitution. Table 9 reports estimates from interacting the number replaced days by type of substitute teacher with the experience gap between the absent and the substitute teachers. It shows that the mitigating effect of certified substitution does not vary with the experience gap, suggesting the existence of other mechanisms.

8.4 Heterogeneity by Month of the School Year

The last mechanism I explore is the role of the pupil-specific human capital gap between the regular and the substitute teachers. According to the theoretical framework, the larger this gap, the bigger the impact of absence. I estimate the impact of absence by month of absence spell. The intuition is that the pupil-specific human capital gap between the regular and substitute teachers is larger at the end of the school year than at the beginning. In September, both regular and substitute teachers have limited knowledge of pupils and the classroom dynamics, but as the regular teacher interacts more and more with her pupils, she gains more and more specific human capital. If the pupil-specific human capital gap is the dominant mechanism, absence spells starting at the end of the year are the most harmful to pupils.

Figure 10 reports estimates of the impact of the number of days of absence/substitution by the starting month of the absence spell. Figure 10a shows the seasonality of the marginal impact of absence. The marginal impact of absence spells starting in Septem-

ber is not statistically significant at the 5 % level. Between October and January, the marginal impact of absence on pupil test scores is equal to -0.06/- 0.08 percent of a standard deviation and is statistically significant at the 5 % level. It then drops to -0.10/ - 0.11 percent of a standard deviation in February and March. The marginal impact of absence is the most negative in June when it reaches a -0.12 % of a standard deviation. Thus, the impact of non-replaced days gets larger as the school year goes by. These results are consistent with pupil-specific human capital as an underlying mechanism. Figures 10b and 10c show the marginal impact of replacement. Both suggest potential alternative mechanisms. They show an increasing trend of the impact of replacement as the school year goes by. This trend is clearer for certified substitute teachers than for non-certified substitute teachers as estimates for the latter are noisier. Figure 10b suggests that the mitigating impact of certified substitute teachers is the largest in June. It would be consistent with the idea that the instruction time that matters the most for pupil test scores is at the very end of the year when more exam-relevant content is being covered. Overall, this analysis provides mixed evidence on the pupil-specific human capital gap as a dominant underlying mechanism.

8.5 Heterogeneity by Type of Absence

Another way to analyse the role of the gap in specific human capital is to compare absences that can be planned with other type of absences. With planned absence, absent teachers have the opportunity to reduce the gap in specific human capital they have with their substitute teachers prior to the absence by sharing content with them, giving them guidelines about pupils, etc. Among all causes of absence, maternity leaves are the most predictable. I therefore compare absence for maternity leave, which can be planned long in advance, with other absences of similar duration (Table 10). I find that the marginal impact of absence for maternity leave is to reduce pupil test scores by 0.036 % of a standard deviation against 0.056 % for non-maternity leave absences of similar length. Both effects are of the same order of magnitude, but the impact of absence for maternity leave is 36 % smaller. This gives suggestive evidence that planned absences are slightly less disruptive for pupils, possibly because of better absent teacher preparation. Certified substitutes are able to mitigate 41.6 % of the effect of absence for maternity leave against 37.5 % of the effect of absence for other reasons. Overall, these estimates give suggestive evidence that planned absences are slightly less disruptive for pupils. They are compatible with the hypothesis that specific human capital is one of the potential mechanisms behind the baseline results.

9 Policy Implications

This paper has two main results: i) teacher absences have a statistically significant negative impact on pupil achievement; ii) this effect is partially mitigated by certified substitute teachers but not by non-certified substitute teachers. This section briefly discusses the main policy implications of these results. The first major policy implication is the importance of having high quality substitute teachers, given the negative impact of teacher absences and the unlikeliness of achieving a zero absence rate (Coles et al., 2007). I perform a back-of-the-envelope calculation of the costs and benefits of replacing all non-certified substitute teachers with certified substitute teachers.

These results also have implications for educational inequalities as non-replaced days and replaced days with a non-certified substitute teacher are concentrated in disadvantaged areas. I perform a back-of-the-envelope calculation of the cumulative contribution, throughout middle school, of non-replaced absence days to educational inequalities between the region with the best substitute teacher coverage (Nice) and the region with the worst substitute teacher coverage (Creteil).

9.1 Replacing All Non-certified Substitute Teachers with Certified Substitute Teachers

I start with the back-of-the-envelope cost and benefit analysis of replacing all non-certified substitute teachers with certified substitute teachers. This calculation relies on the assumption that such policy would not change the composition of the stock of regular certified teachers. The annual cost of such policy is equal to the difference between the annual salary of certified substitute teachers and non-certified substitute teachers. Certified substitute teachers earn 3,600 € per year more than non-certified teachers. There are 23,035 non-certified teachers in the dataset: replacing them with certified teachers would cost 3600*23,035= 82,926,000 € per year. The benefit of this policy would be to reduce the negative impact of teacher absence on pupil test scores. On average, substitute teachers replace 10 days of absence per year, among which 7.73 are replaced by certified substitute teachers. As the marginal impact of one replaced day with a certified substitute teacher is equal to 0.007 % of a standard deviation, the average yearly mitigating effect on pupil test scores of replacement with a certified substitute teacher is equal to 0.007 * 7.73= 0.05 % of a standard deviation. If all replaced days were covered by certified substitute teachers, the average yearly mitigating effect on pupil test scores of replacement with a certified substitute teacher would be equal to 0.007 *10= 0.07 % of a standard deviation.

9.2 Contribution to Educational Inequalities

I now turn to the back-of-the-envelope calculation of the cumulative contribution, throughout middle school, of non-replaced absence days as well as replaced days with a non-certified substitute teacher to educational inequalities between the two extreme regions of Nice and Creteil. Nice is the region where teacher absence is best covered (around 45 %, including 30 % with certified substitute teachers) whereas Creteil is the region with the worst coverage (around 6 %, including 3 % with certified substitute teachers). This calculation relies on the assumption that the impact of non-replaced days is constant across grades in middle school. The pupil test scores gap between Nice and Creteil is equal, on average, to 0.11 standard deviation over the 2007-2015 period. In Creteil, pupils experience on average 2.93 more non-replaced day/day with a non-certified substitute teacher than pupils in Nice. As pupils generally spend four years in middle school, the cumulative average gap in non-replaced days at the end of middle school between pupils in Nice and pupils in Creteil is equal to 11.72 days. Therefore, as the effect of one non-replaced day/day with a non-certified substitute teacher is equal to 0.027 % of a standard deviation, non-replaced days represent 0.00027*11.72/0.11=2.9 % of the achievement gap between Creteil and Nice at the end of middle school.

10 Conclusion

Using a unique French administrative dataset matching, for each absence spell, each missing secondary school teacher to her substitute teacher, this paper (a) estimates the effect of teacher absence on pupil test achievement; (b) studies how the effect of teacher absence can be mitigated through the assignment and quality of substitute teachers.

I find that the marginal impact of one additional day of absence is to reduce pupil achievement by 0.03 % of a standard deviation. As teachers miss an average of 13 days per year, the average effect of their absence is to reduce pupil test scores by around 0.40 % of a standard deviation. Certified substitute teachers can compensate 25 % of this negative impact, while non-certified substitute teachers do not have a statistically significant impact. I also provide suggestive evidence on the possible underlying mechanisms, including the gap in general and specific human capital between the regular and the substitute teachers.

This paper has important implications for public policy. It highlights the importance of having high quality substitute teachers, given the negative impact of teacher absences. It also has implications for educational inequalities as non-replaced days and

replaced days with a non-certified substitute teacher are concentrated in disadvantaged areas.

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Tables

Table 1 – Substitute Teachers Characteristics

	Regular Certified Teacher	**Certified Sub.**	**Non-Certified Sub.**
A. **Demographics**			
Male	0.36	0.39	0.43
	(0.48)	(0.49)	(0.50)
Age	43.8	39.0	37.9
	(10.3)	(10.5)	(8.9)
Average Experience (in years)	14.1	10.0	4.6
	(8.3)	(8.8)	(10.2)
A year or less of experience	0.02	0.13	0.32
	(0.12)	(0.34)	(0.47)
B. **Certification**			
Agrégation	0.05	0.05	–
	(0.23)	(0.22)	
CAPES	0.77	0.74	–
	(0.42)	(0.44)	
Other	0.17	0.21	–
	(0.38)	(0.41)	
C. **Evaluations**			
Classroom Observation Grade (/60)	46.82	44.84	11.85
	(5.99)	(6.39)	(9.59)
Headteacher Grade (/40)	39.02	39.15	13.86
	(10.05)	(11.82)	(8.70)
Number of teachers	193,766	67,541	23,035

Notes: Standard deviation in parenthesis. Other: old and outdated classifications that have disappeared today and are hold mostly by very experienced teachers. Source: Teacher absence and replacement datasets and pupil achievement datasets, 2007-2015, French Ministry of Education.

Table 2 – Performance at the Certification Examination of the Non-Certified Teachers who Take This Examination On-the-job

	Non-Certified Teachers Candidates		**Other Candidates**	
	Agreg.	CAPES	Agreg.	CAPES
A. Demographics				
Age (in years)	37.72	35.17	31.05	28.18
	(7.75)	(7.68)	(8.32)	(6.65)
Male	0.53	0.39	0.46	0.35
	(0.50)	(0.48)	(0.49)	(0.48)
B. Performance				
Passing Rate	0.03	0.16	0.15	0.33
	(0.18)	(0.37)	(0.36)	(0.47)
Written Part Grade (/20)	3.91	5.67	6.25	7.30
	(2.52)	(3.14)	(3.61)	(3.69)
Oral Part Grade (/20)	7.00	7.30	8.09	8.50
	(3.78)	(4.17)	(3.83)	(4.58)
Nb of observations	286	1,232	8,037	11,779

Note: Standard deviation in parenthesis. By definition, non-certified teachers do not have any teacher certification. Sample: non-certified teachers who take the same certification examinations as regular teachers and certified substitute teachers, while they are on the job as non-certified teachers. Source: Teacher certification datasets, 2007, French Ministry of Education.

Table 3 – Relationship between Absence/Replacement and Teacher Characteristics

	# Abs. Days		Share Replaced Days		Share Replaced x Non-certified Sub.		Share Replaced x Certified Sub.	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Experience (Ref: 6 + years)								
One year or less of experience	-4.976***	-4.099	-0.043***	-0.056***	-0.012**	-0.014	-0.031***	-0.045***
	(1.255)	(2.479)	(0.008)	(0.016)	(0.005)	(0.009)	(0.006)	(0.011)
Two years of experience	-4.854***	-5.415***	-0.026***	-0.0382***	-0.008**	-0.017***	-0.018***	-0.020**
	(0.613)	(1.061)	(0.005)	(0.008)	(0.002)	(0.005)	(0.004)	(0.007)
Three years of experience	-3.475***	-4.059***	-0.019***	-0.025***	-0.005*	-0.011***	-0.013***	-0.0138**
	(0.455)	(0.658)	(0.004)	(0.006)	(0.002)	(0.003)	(0.003)	(0.005)
Four years of experience	-1.706***	-2.711***	-0.006	-0.012**	-0.000	-0.006	-0.006	-0.007
	(0.377)	(0.532)	(0.003)	(0.004)	(0.002)	(0.003)	(0.002)	(0.004)
Five years of experience	0.637	-0.681	0.008**	0.000	0.007***	0.000	0.001	0.000
	(0.350)	(0.449)	(0.002)	(0.003)	(0.001)	(0.002)	(0.002)	(0.003)
Seniority (Ref.: 6 + years)								
One year of seniority	5.320	22.930	0.498**	0.649**	0.332	0.294	0.167	0.356
	(10.26)	(13.150)	(0.210)	(0.257)	(0.200)	(0.263)	(0.177)	(0.319)
Two years of seniority	3.084***	0.004	0.018***	0.004	0.007***	-0.002	0.012***	0.006
	(0.268)	(0.437)	(0.001)	(0.003)	(0.001)	(0.002)	(0.001)	(0.003)
Three years of seniority	1.545***	1.001**	0.012***	0.0111***	0.005***	0.002	0.008***	0.009***
	(0.223)	(0.365)	(0.00171)	(0.002)	(0.000)	(0.001)	(0.001)	(0.002)
Four years of seniority	1.368***	1.112***	0.011***	0.0101***	0.005***	0.002	0.006***	0.007***
	(0.222)	(0.315)	(0.001)	(0.002)	(0.000)	(0.001)	(0.001)	(0.002)
Five years of seniority	0.695***	0.374	0.007***	0.004**	0.004***	0.001	0.003***	0.003
	(0.205)	(0.275)	(0.001)	(0.002)	(0.000)	(0.001)	(0.001)	(0.001)
Pupil Composition								
Prop. of financial aid pupils	-0.492	0.901	-0.007***	0.002	0.003***	0.001	-0.009***	0.001
	(0.339)	(0.530)	(0.002)	(0.006)	(0.001)	(0.002)	(0.001)	(0.005)
Gender								
Male	-4.688***		-0.029***		-0.013***		-0.017***	
	(0.124)		(0.000)		(0.000)		(0.000)	
Certification Level (Ref: Capes)								
Agrégation	0.383		0.003		0.002*		0.001	
	(0.219)		(0.002)		(0.000)		(0.001)	
Teaching subject (Ref.: History)								
French	0.855***		-0.002*		0.002***		-0.003***	
	(0.158)		(0.001)		(0.0005)		(0.002)	
Math	-0.851***		-0.002**		0.007***		-0.010***	
	(0.144)		(0.001)		(0.000)		(0.000)	
Teacher - school fixed effects	No	Yes	No	Yes	No	Yes	No	Yes
Nb. of obs.	282,001	282,001	282,001	282,001	282,001	282,001	282,001	282,001

Notes: Each column corresponds to a single regression. Results are reported in percentage of a standard deviation. All regressions include year fixed effects. Robust standard errors clustered by teacher-school between parentheses. Asterisks denote statistical significance at the 1 % (***) and 5 % (**) levels. Source: Teacher datasets and school datasets, 2007-2015, French Ministry of Education.

Table 4 – Effect of Teacher Absence and Replacement on Pupil Achievement

in % of a SD	(1)	(2)	(3)
# days of absence	-0.130***	-0.044***	-0.028***
	(0.009)	(0.006)	(0.005)
# replaced days	0.056***	0.010	0.010
	(0.011)	(0.006)	(0.006)
Average # of days of absence	[13.14]	[13.14]	[13.14]
Average # of replaced days	[10.06]	[10.06]	[10.06]
Teacher-school fixed-effect	No	Yes	Yes
Classroom fixed-effect	No	No	Yes
Number of observations	32,290,084	32,290,084	32,290,084

Notes: Each column corresponds to a single regression. Results are reported in percentage of a standard deviation. All regressions include year x subject fixed effects, pupils' background controls (parental profession and financial aid status) as well as teacher experience and seniority. Teacher experience and seniority are included as quadratic functions. Robust standard errors clustered by school between parentheses. Asterisks denote statistical significance at the 1 % (***) and 5 % (**) levels. Source: Teacher absence and replacement datasets and pupil achievement datasets, 2007-2015, French Ministry of Education.

Table 5 – Effect of Teacher Absence and Replacement on Pupil Achievement by Type of Substitute Teacher

in % of a SD	(1)	(2)	(3)
# days of absence	-0.132***	-0.046***	-0.027***
	(0.010)	(0.005)	(0.005)
# replaced days x certified sub.	0.072***	0.017***	0.007***
	(0.011)	(0.006)	(0.005)
# replaced days x non-certified sub.	0.024**	-0.010	-0.006
	(0.012)	(0.007)	(0.007)
Average # days of abs.	[13.14]	[13.14]	[13.14]
Average # replaced days certified sub.	[7.73]	[7.73]	[7.73]
Average # replaced days non-certified sub.	[2.22]	[2.22]	[2.22]
Teacher-school fixed-effect	No	Yes	Yes
Classroom fixed-effect	No	No	Yes
Number of observations	32,290,084	32,290,084	32,290,084

Notes: Each column corresponds to a single regression. Results are reported in percentage of a standard deviation. All regressions include year x subject fixed effects, pupils' background controls (parental profession and financial aid status) as well as teacher experience and seniority. Teacher experience and seniority are included as quadratic functions. Robust standard errors clustered by school between parentheses. Asterisks denote statistical significance at the 1 % (***) and 5 % (**) levels. Source: Teacher absence/replacement datasets and pupil achievement datasets, 2007-2015, French Ministry of Education.

Table 6 – Robustness Check: Placebo Test of the Effect of Absence and Replaced Days of "Other subject" Teacher on Pupil Achievement

	Math Exam		French Exam		History Exam	
	(1)	(2)	(3)	(4)	(5)	(6)
A. Math Teacher						
# Days of Absence	-0.081***	-0.078***	-0.00	0.004	-0.009	-0.002
	(0.009)	(0.009)	(0.00)	(0.009)	(0.010)	(0.010)
# Replaced Days	0.001		-0.00		0.000	
	(0.001)		(0.00)		(0.000)	
# Replaced Days x certified Sub.		0.007		-0.007		-0.002
		(0.011)		(0.010)		(0.011)
# Replaced Days x non-certified Sub.		-0.012		-0.004		0.003
		(0.011)		(0.010)		(0.011)
Math Teacher - School Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
B. French Teacher						
(with French Teacher -school fixed effects)						
# Days of Absence	-0.011	-0.007	-0.044***	-0.035***	-0.020	-0.016
	(0.007)	(0.007)	(0.007)	(0.005)	(0.013)	(0.10)
# Replaced Days	-0.002		0.013		0.013	
	(0.009)		(0.009)		(0.009)	
# Replaced Days x certified Sub.		0.004		0.016**		0.017
		(0.008)		(0.008)		(0.010)
# Replaced Days x non-certified Sub.		-0.012		-0.005		0.007
		(0.010)		(0.010)		(0.010)
French Teacher - School Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
C.History Teacher						
# Days of Absence	-0.004	-0.000	-0.005	-.001	-0.038***	- 0.035***
	(0.099)	(0.010)	(0.009)	(0.010)	(0.010)	(0.011)
# Replaced Days	-0.013		-0.003		0.013	
	(0.011)		(0.011)		(0.012)	
# Replaced Days x certified Sub.		-0.014		-0.001		0.013
		(0.011)		(0.011)		(0.013)
# Replaced Days x non-certified Sub.		-0.025		-0.013		-0.002
		(0.020)		(0.011)		(0.014)
History Teacher - School Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Each column corresponds to a single regression. The dependent variable is pupil test scores in 9th grade by subject: Math (columns 1 and 2), French (columns 3 and 4) and History (columns 5 and 6). Panel A reports the impact of Math teachers' absence/replacement, Panel B the impact of French teachers' and Panel C the impact of History teachers'. For example, column 1 of panel A reports the impact of Math teachers' absence on pupils' Math test scores, controlling for Math teacher-school fixed effects. Column 3 of panel A reports the impact of Math teachers' absence on pupils' French test scores, controlling for Math teacher-school fixed effects.
Results are reported in percentage of a standard deviation. Regressions include, additionally to the relevant teacher-school fixed effects, year fixed-effects, pupils' background controls (parental profession and financial aid status) as well as teacher experience and seniority. Teacher experience and seniority are included as quadratic functions. Robust standard errors clustered by school. Asterisks denote statistical significance at the 1 % (***) and 5 % (**) levels. Source: Teacher absence/replacement datasets and pupil achievement datasets, 2007-2015, French Ministry of Education.

Table 7 – Robustness Check: Placebo Test of the Effect of Absence and Replaced Days of Previous and Following Year on Pupil Achievement

	Previous year		Following year	
	(1)	(2)	(3)	(4)
# Days of Absence	0.004	0.003	0.002	0.000
	(0.019)	(0.020)	(0.013)	(0.013)
# Replaced Days	0.015		0.004	
	(0.023)		(0.018)	
# Replaced Days x Certified Sub.		0.023		0.003
		(0.027)		(0.020)
# Replaced Days x Non-certified Sub.		0.008		0.018
		(0.029)		(0.027)
Teacher - school fixed effect	Yes	Yes	Yes	Yes
Classroom Fixed Effect	Yes	Yes	Yes	Yes
Number of observations	24,217,564	24,217,564	24,217,564	24,217,564

Notes: Each column corresponds to a single regression. In columns (1) and (2), the number of days of absence, number of replaced days and number of replaced days with the two types of substitute teachers of the previous year are used as independent variables. Column (1) shows that the marginal impact of one additional day of absence and replacement of the teacher in the year $n-1$ does not have any statistically significant impact on her pupil test scores, assigned to her during the year n. In columns (3) and (4), the number of days of absence, number of replaced days and number of replaced days with the two types of substitute teachers of the following year are used as independent variables.
Results are reported in percentage of a standard deviation. The regression includes year x subject fixed effects, pupils' background controls (parental profession and financial aid status) as well as teacher experience and seniority. Teacher experience and seniority are included as quadratic functions. Robust standard errors clustered by teacher-school between parentheses. Asterisks denote statistical significance at the 1 % (***) and 5 % (**) levels. Source: Teacher absence/replacement datasets and pupil achievement datasets, 2007-2015, French Ministry of Education.

Table 8 – Robustness Check: Effect of Teacher Absence Spells During Holidays on Pupil Achievement

in % of a SD	(1)	(2)
# days of absence during school holidays	0.029	0.027
	(0.035)	(0.024)
Teacher-School fixed-effect	No	Yes
Classroom fixed-effect	No	Yes
Number of observations	32,290,084	32,290,084

Notes: Results are reported in percentage of a standard deviation. The regression includes year x subject fixed effects, pupils' background controls (parental profession and financial aid status) as well as teacher experience and seniority. Teacher experience and seniority are included as quadratic functions. Robust standard errors clustered by school between parentheses. Source: Teacher absence/replacement datasets and pupil achievement datasets, 2007-2015, French Ministry of Education.

Table 9 – Effect of Absence and Replacement on Pupil Achievement by Experience Gap between the Absent Teacher and the Substitute Teacher

in % of a SD of pupil test scores	
# days of absence	-0.039***
	(0.005)
# replaced days x certified sub.	0.015**
	(0.008)
# replaced days x certified sub. x exp. gap absent/certified sub.	-0.000
	(0.000)
# replaced days x non-certified sub.	0.014
	(0.013)
# replaced days x non-certified sub. x exp. gap absent/non-certified sub.	- 0.001**
	(0.000)
Average # days of abs.	[13.14]
Average # replaced days certified sub.	[7.73]
Average # replaced days non-certified sub.	[2.22]
Teacher-school fixed-effect	Yes
Classroom fixed-effect	Yes
Number of observations	32,290,084

Notes: Results are reported in percentage of a standard deviation. The regression includes year x subject fixed effects, pupils' background controls (parental profession and financial aid status) as well as teacher experience and seniority. Teacher experience and seniority are included as quadratic functions. Robust standard errors clustered by school between parentheses. Asterisks denote statistical significance at the 1 % (***) and 5 % (**) levels. Source: Teacher absence/replacement datasets and pupil achievement datasets, 2007-2015, French Ministry of Education.

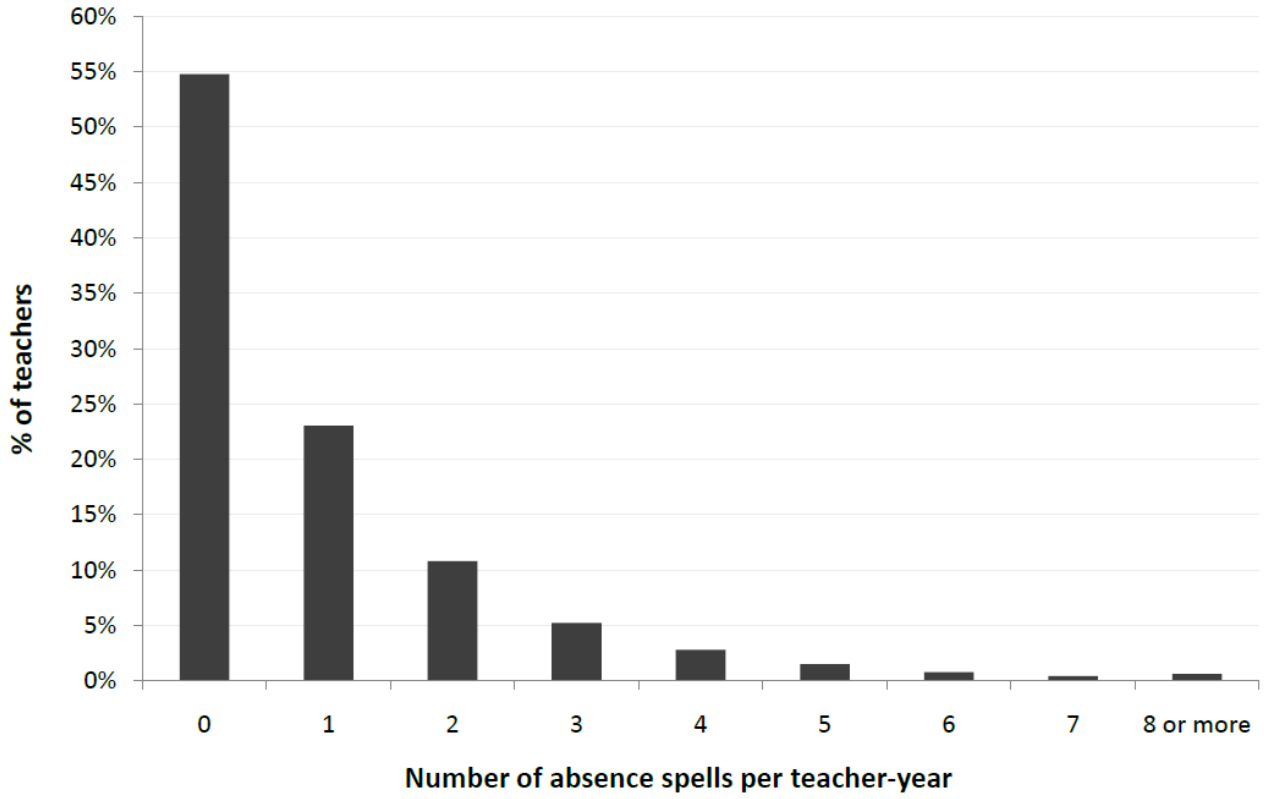
Table 10 – Impact of Absence and Replacement on Pupil Achievement by Type of Absence (Maternity leave vs. others)

in % of a SD	# Days of Abs. (1)	# Replaced Days x Certified Sub. (2)	# Replaced Days x Non-Certified. Sub. (3)
Maternity Leave	-0.036***	0.015***	0.002
	(0.007)	(0.008)	(0.009)
Average # days of abs.	[53.67]	[21.67]	[12.14]
Non Maternity Leave	-0.056***	0.021***	-0.060
(same length)	(0.007)	(0.008)	(0.030)
Average # days of abs.	[49.30]	[16.69]	[8.42]

Notes: Estimates corresponds to a single regression with the preferred specification. Results are reported in percentage of a standard deviation. The regression includes year x subject fixed effects, pupils' background controls (parental profession and financial aid status) as well as teacher experience and seniority. Teacher experience and seniority are included as quadratic functions. Robust standard errors clustered by teacher-school between parentheses. Asterisks denote statistical significance at the 1 % (***) and 5 % (**) levels. Source: Teacher absence/replacement datasets and pupil achievement datasets, 2007-2015, French Ministry of Education.

Figures

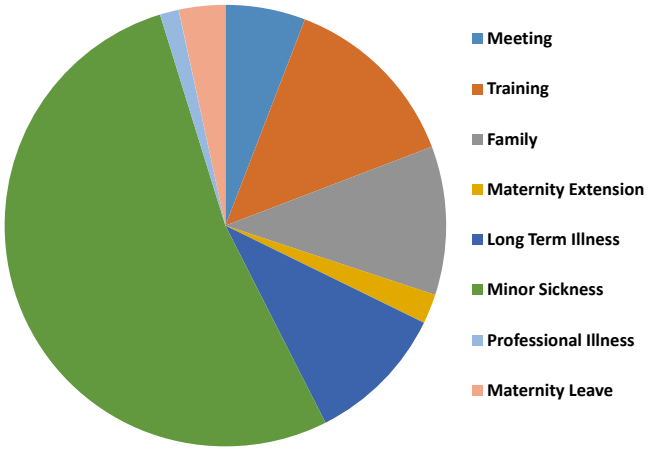
Figure 1 – Distribution of Absence Spells by Teacher-Year



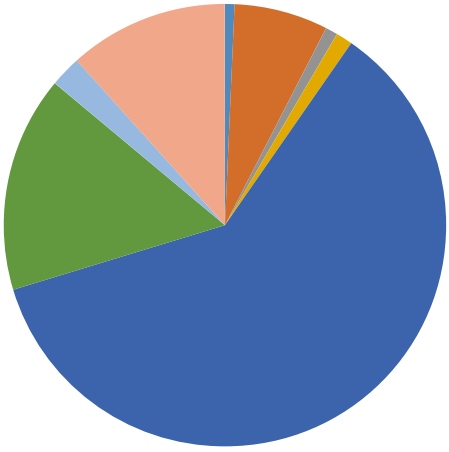
Note: This figure shows the distribution of the number of absence spells taken per teacher-year. Source: Teacher absence datasets, 2007-2015, French Ministry of Education.

Figure 2 – Distribution of Absence Spells and Days per Type of Absence

(a) Distribution of the Number of Absence Spells per Type of Absence

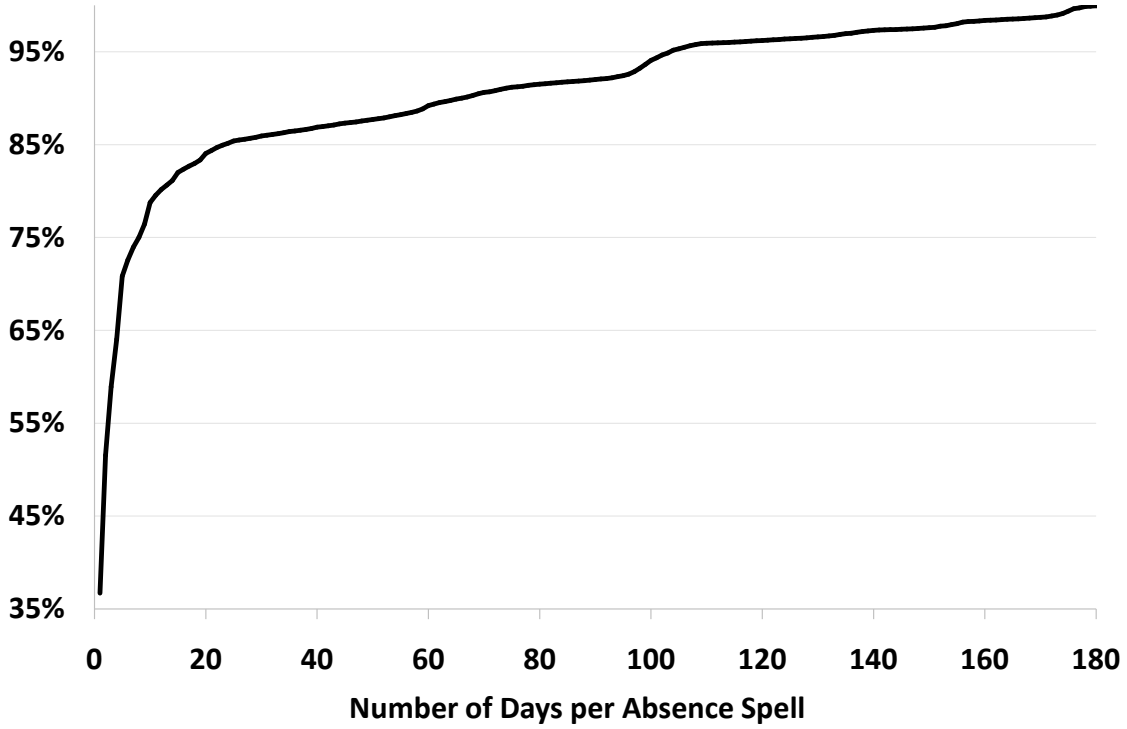


(b) Distribution of the Number of Absence Days per Type of Absence



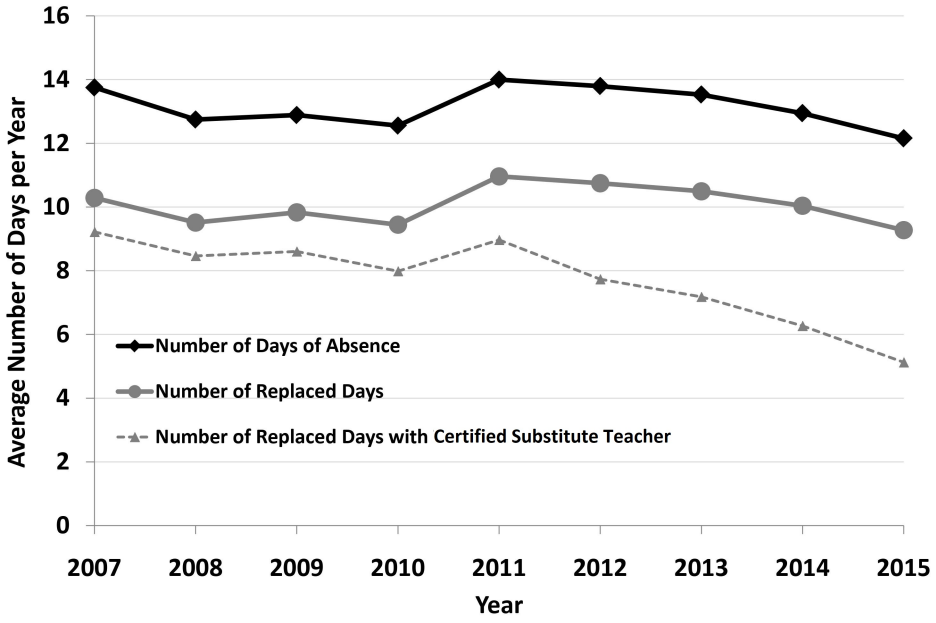
Notes: Figure 2a plots the distribution of the number of absence spells (2006-2015) per type of absence. Figure 2b plots the distribution of the number of absence days per type of absence. Source: Teacher absence/replacement datasets, 2007-2015, French Ministry of Education.

Figure 3 – Cumulative Distribution of Length of Absence Spells



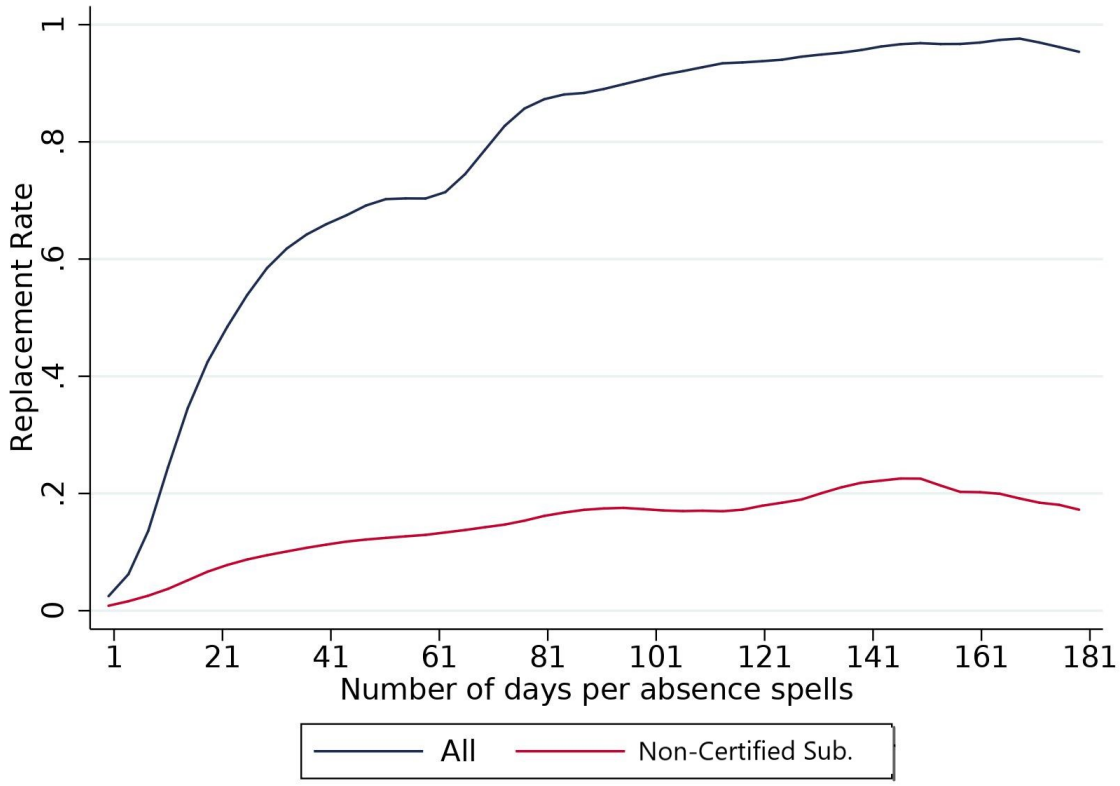
Notes: This figure shows the cumulative distribution of the length, in number of days, of teacher absence spells. Source: Teacher absence datasets, 2007-2015, French Ministry of Education.

Figure 4 – Number of Days of Absence and Replacement per Year



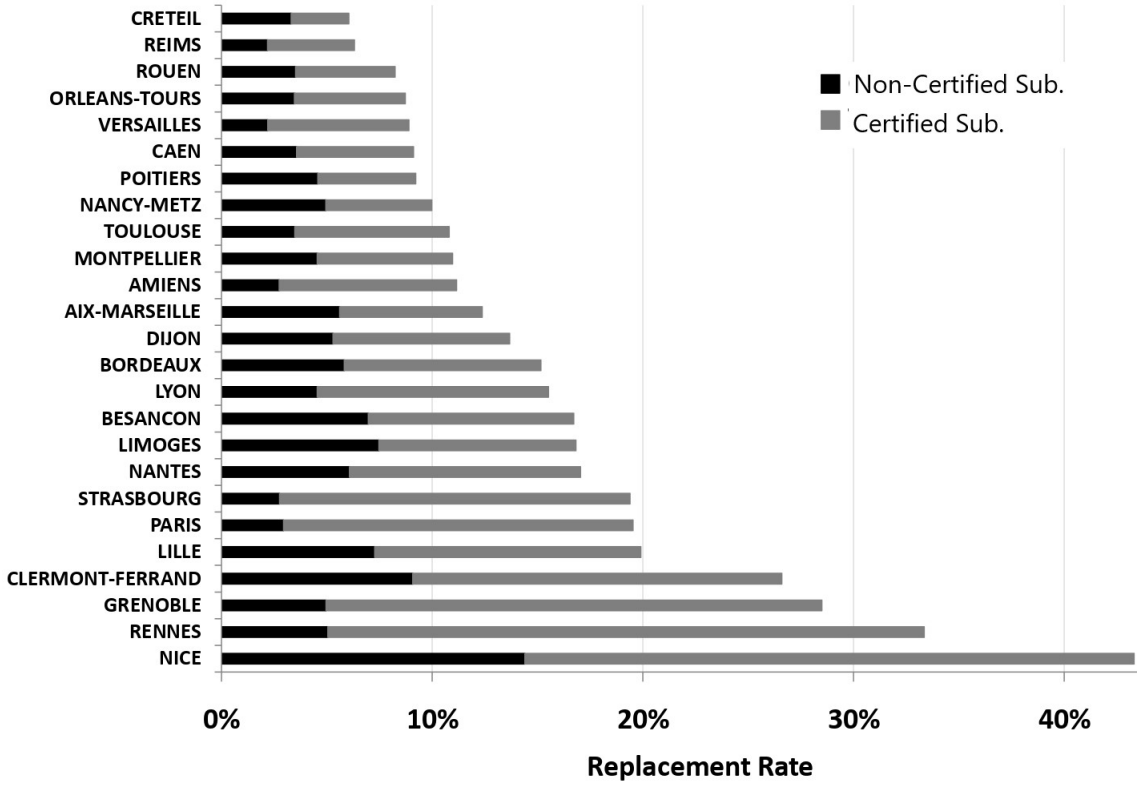
Notes: This figure shows the average number of days of absence, number of replaced days and number of replaced day with a certified substitute teacher. Source: Teacher absence datasets, 2007-2015, French Ministry of Education.

Figure 5 – Replacement Rate per Length of Absence Spell



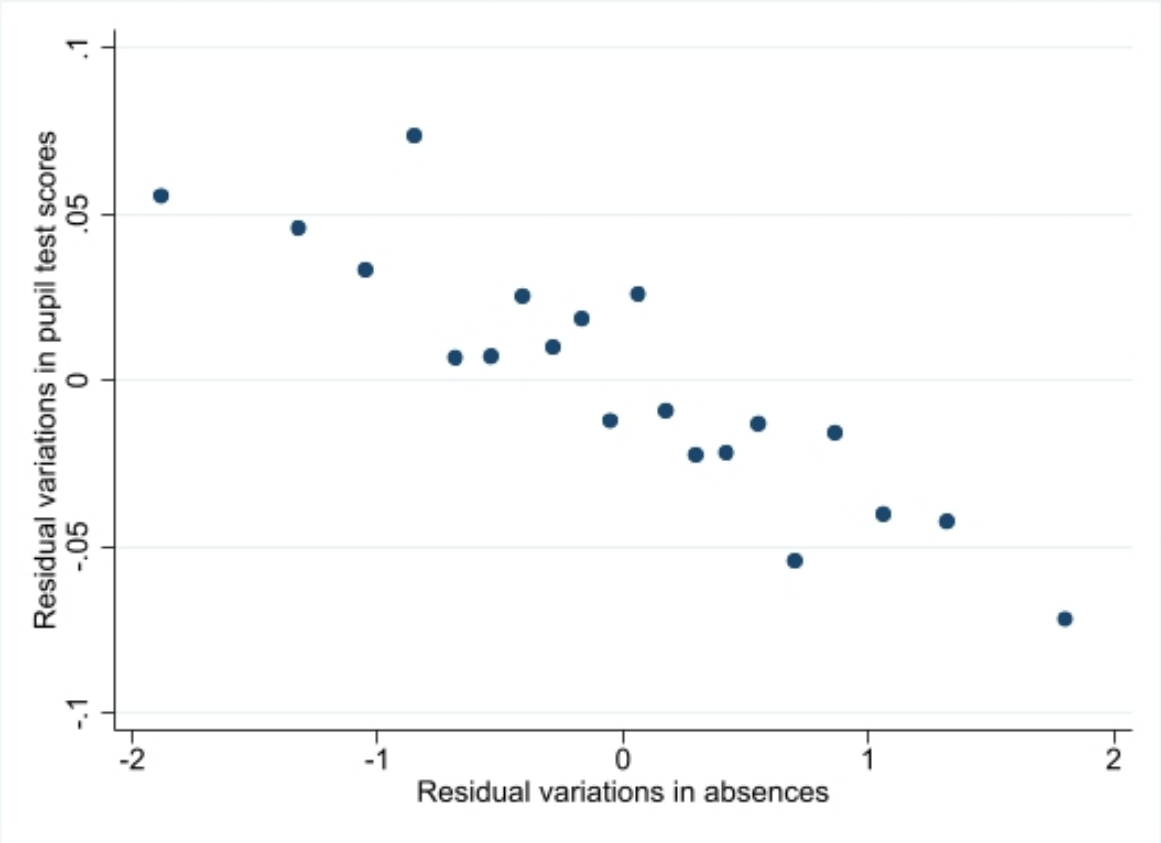
Notes: This figure shows the replacement rate per length of absence spell. The blue line shows the replacement rate irrespective of the certification status of the substitute teacher. The red line shows the replacement rate with a non-certified substitute teacher. Source: Teacher absence datasets, 2007-2015, French Ministry of Education.

Figure 6 – Replacement Rate per Region



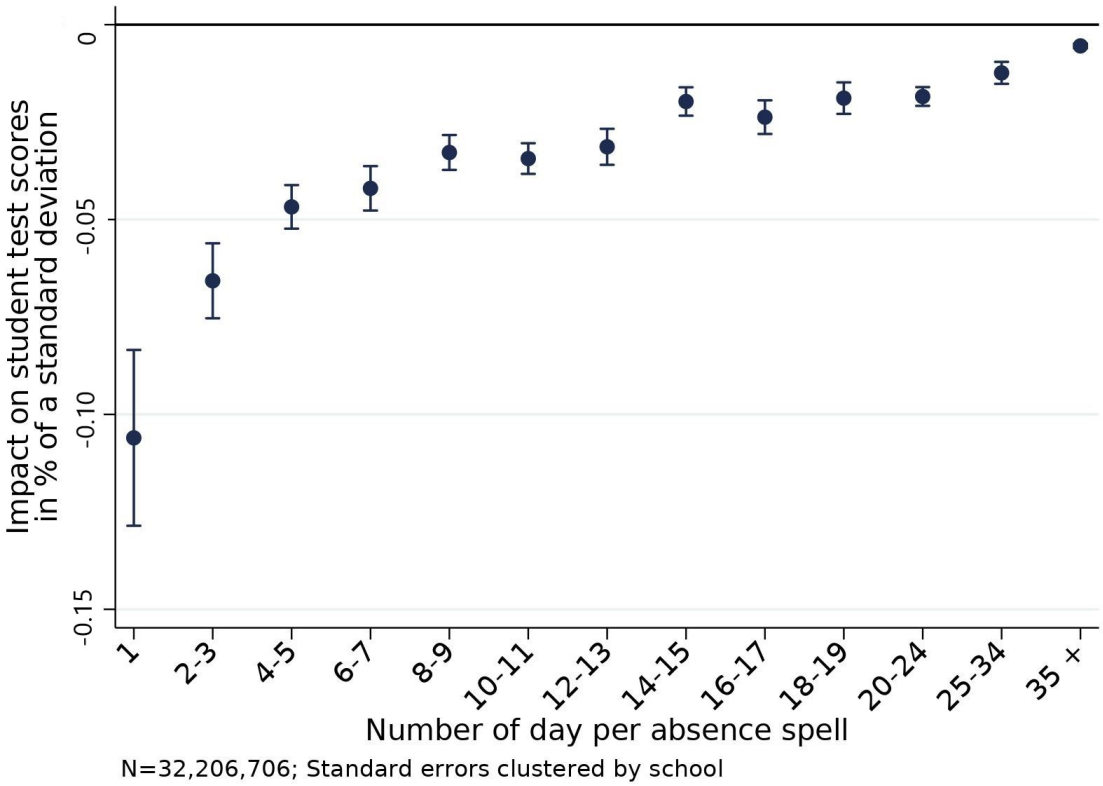
Notes: This figure shows the replacement rate per region. It decomposes the replacement rate by substitute teachers' certification status. Source: Teacher absence/replacement datasets, 2007-2015, French Ministry of Education.

Figure 7 – Relationship between Residual Variation in Teacher Absences and Residual Variation in Pupil Test Scores



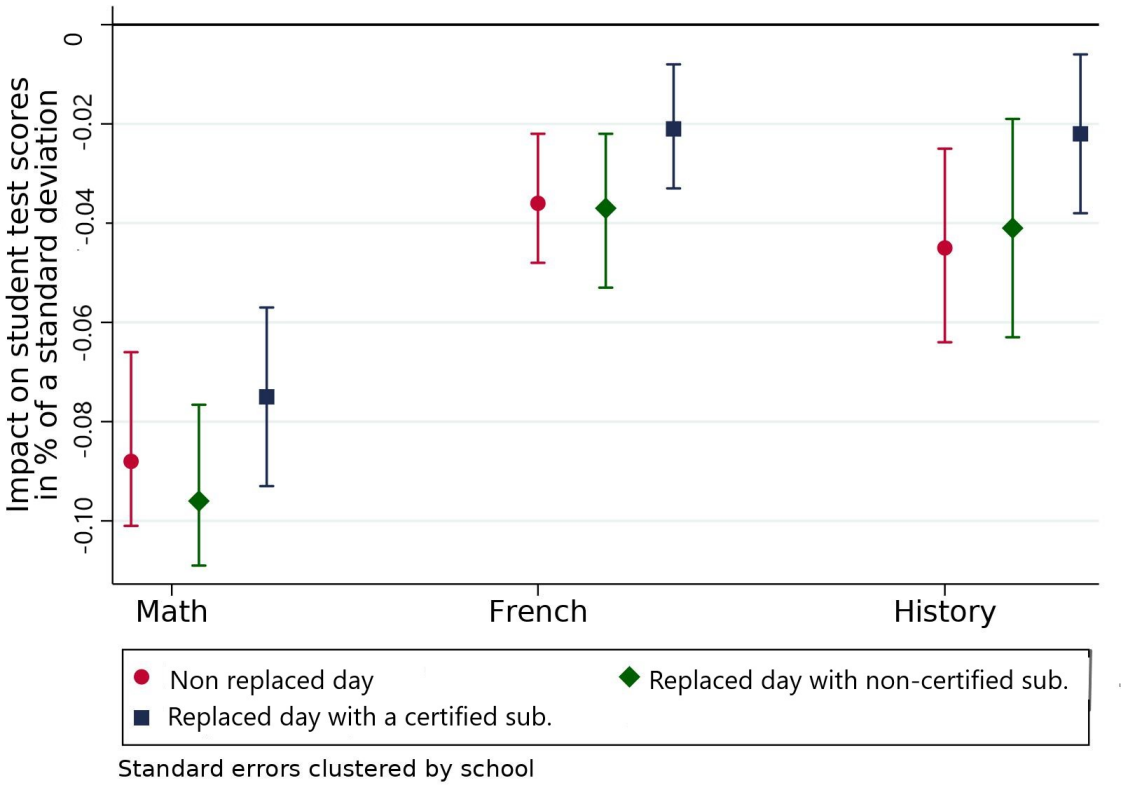
Notes: This figure shows a binned scatter plot of the relationship between the residual variation in absence days and residual variation in test scores, after estimating the preferred specification. Source: Teacher absence/replacement datasets and pupil achievement datasets, 2007-2015, French Ministry of Education.

Figure 8 – Marginal Impact of Non-replaced Day by Length of Absence Spell



Notes: Results are reported in percentage of a standard deviation, with confidence intervals at the 5 % level. All reported estimates correspond to a single regression with the preferred specification. The regression includes year x subject fixed effects, pupils' background controls (parental profession and financial aid status) as well as teacher experience and seniority. Teacher experience and seniority are included as quadratic functions. Robust standard errors clustered by school. Source: Teacher absence/replacement datasets and pupil datasets, 2007-2015, French Ministry of Education.

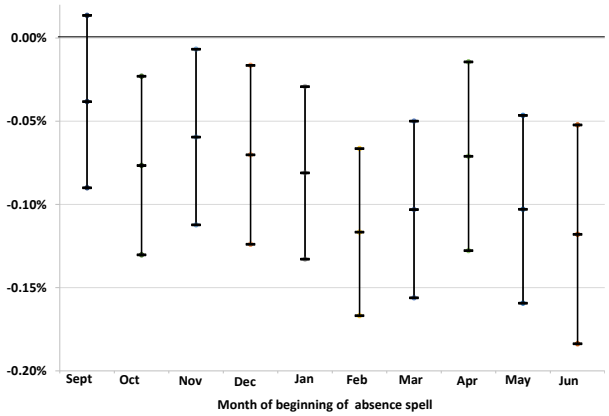
Figure 9 – Impact of Absence and Replacement by Teaching Subject



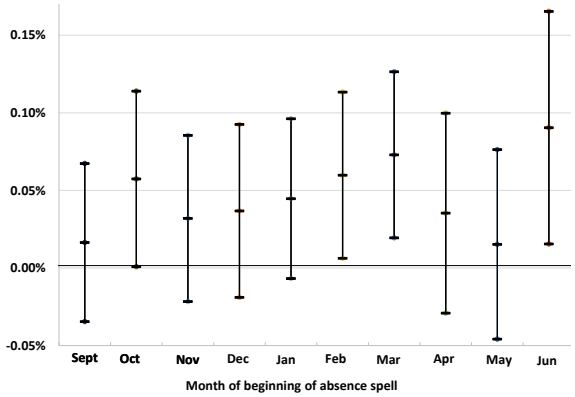
Notes: Estimates by subject are estimated through interaction terms. For each subject, the first reported estimates corresponds to the number of days of non-replaced absence, the second to the number of days with a non-certified teacher and the third to the number of days with a certified substitute teacher.
Results are reported in percentage of a standard deviation, with confidence intervals at the 5 % level. All reported estimates correspond to a single regression with the prefered specification. Robust standard errors clustered by school. Source: Teacher absence/replacement datasets and pupil datasets, 2007-2015, French Ministry of Education.

Figure 10 – Impact of Absence and Replacement per Month of the Year

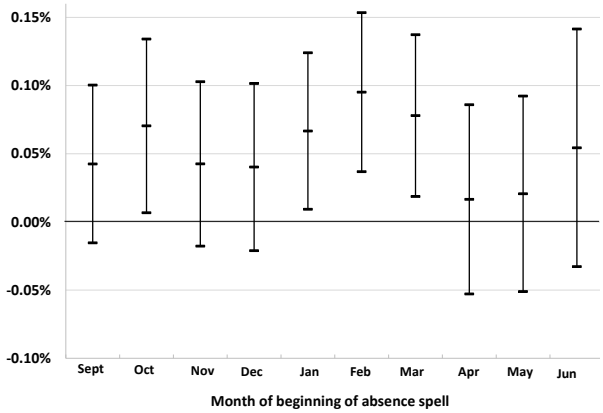
(a) Impact of Absence



(b) Impact of Certified Substitute



(c) Impact of Non-Certified Substitute



Notes: Estimates correspond to a single regression with the preferred specification and are reported in percentage of a standard deviation, with confidence intervals at the 5 % level. Figure 10a reports the marginal impact of absence by month of absence spell, Figure 10b the marginal impact of one additional day with a certified substitute teacher by month of absence spell and Figure 10c the marginal impact of one additional day with a non-certified substitute teacher by month of absence spell. Source: Teacher absence/replacement datasets and pupil datasets, 2007-2015, French Ministry of Education.

Appendix A: Detailed Conceptual Framework

I present a highly stylised conceptual framework to understand the intuition of my empirical analysis. I essentially build on Herrmann and Rockoff (2012) and add to their framework the potential mechanisms underlying the effect of teacher absence and substitution on teacher productivity.

Consider $q_{j,i,t}$ the productivity of a representative teacher j during a specific hour of teaching t with pupil i. The average hourly productivity of teacher j over her hours of teaching with pupil i, indexed from 1 to $T_{j,i}$ writes:

$$q_{j,i} = \frac{1}{T_{j,i}} \sum_{t=1}^{T_{j,i}} q_{j,i,t} \tag{2}$$

Crucially, I assume the average hourly productivity to be strictly increasing in the number of hours T_j teacher j spends instructing her pupil i:

$$q_{j,i} = q_j(T_{j,i}), \text{ with } \frac{\delta q_{j,i}(T_{j,i})}{\delta T_{j,i}} > 0 \tag{3}$$

The intuition is that teachers acquire, over their hours of teaching, pupil-specific human capital, which contributes positively to their average productivity. Existing empirical evidence backs this intuition. Duflo, Dupas and Kremer (2011) suggest teachers adjust the level at which they teach in response to changes in class composition. Herrmann and Rockoff (2012) find daily productivity losses from absence decline with the length of an absence spell, consistent with substitute teachers learning on-the-job. Thus, I assume the longer teachers teach their pupils, the better they are at it. This may be because they get to know and adjust to their pupils, and have more time to implement a long-term instructional strategy.

I write total productivity $Q_{T_{j,i}}$ over hours of teaching indexed from 1 to $T_{j,i}$ as a function of hourly productivity:

$$Q_{T_{j,i}} = f_{T_{j,i}}(q_{j,i,1}, q_{j,i,2}, ..., q_{j,i,T_{j,i}}), \text{ where } j = \begin{cases} r \text{ if the regular teacher is teaching} \\ s \text{ if the substitute teacher } s \text{ is teaching} \end{cases} \tag{4}$$

From the pupil i perspective, the total number of planned hours of instruction T_i writes:

$$T_i = T_{i,r} + T_{i,s} + T_{i,a} \tag{5}$$

where $T_{i,a}$ is the number of instruction hours lost by pupil i when her regular teacher is absent and no substitute teacher is assigned. I write $Y_{i,T}$, pupil i output over T, as a function g_T of the sum of regular teacher r and potential substitute teacher s respective productivity, lost instruction time $T_{i,a}$ and an idiosyncratic error ϵ_{i,T_i} (other inputs):

$$Y_{i,T_i} = g_T(f_{T_{i,r}} + f_{T_{i,s}}, T_{i,a}, \epsilon_{i,T_i}) \tag{6}$$

I use the standard education production function framework (Todd and Wolpin, 2003), and I assume $f_{T_{i,j}}$ and g_T to be additive and separable:

$$Y_{i,T_i} = T_{i,r}q_r(T_{i,r}).\alpha + T_{i,s}q_s(T_{i,s}).\beta + T_{i,a}.\gamma + \epsilon_{i,T_i} \tag{7}$$

Empirically, we observe two main different cases: 1) The regular teacher is absent and no substitute teacher is assigned; 2) The regular teacher is absent and a substitute teacher is assigned.

Case 1. It corresponds to $T_{i,s} = 0$, $T_{i,a} > 0$ and $T_{i,r} = T_i - T_{i,a}$. The marginal effect of teacher absence writes:

$$\frac{\delta Y_{i,T_i}}{\delta T_{i,a}} = -\alpha[\underbrace{q_r(T_i - T_{i,a})}_{(a)} + \underbrace{\frac{\delta q_r(T_i - T_{i,a})}{\delta T_{i,a}}(T_i - T_{i,a})]}_{(b)} + \underbrace{\gamma}_{(c)} \tag{8}$$

Each term of this equation can be interpreted as follows:

- Term (a): The more productive the regular teacher is, the greater the output loss from her absence
- Term (b): It can be interpreted as the disruptive effect of the absence of the regular teacher. It is the additional pupil-specific human capital that teacher r would have acquired during her absence. Intuitively, teacher r's absence gives her less time to know her pupils and creates discontinuities in her long-term instructional strategy.
- Term (c): This is the variation in pupil output caused directly by the fact that pupils do not have class during teacher r absence. Its sign can depend on the quality of the regular teacher and on whether the absence was expected. For example, if the absence was expected and the regular teacher is forward-looking, she can give them extra homework: they have material to study during her absence, which can mitigate the negative impact of her absence. This term can also depend on the ability of pupils and their parents to adapt to the absence spell. The longer the absence spell, the more pupils or their parents can put in place alternative compensating strategies such as private tutoring.

Overall, in case 1, the marginal effect of teacher absence will be negative unless $\gamma > \alpha[q_r(T_i - T_{i,a}) + \frac{\delta q_r(T_i - T_{i,a})}{\delta T_{i,a}}(T_i - T_{i,a})]$, i.e. unless pupils use their lost instruction hours so efficiently that these hours are more productive than the instruction hours they would have had with their missing regular teacher.

Case 2. It corresponds to $T_{i,s} > 0$, $T_{i,a} = 0$ and $T_{i,r} = T_i - T_{i,s}$. The marginal effect of teacher absence writes:

$$\frac{\delta Y_{i,T_i}}{\delta T_{i,s}} = -\alpha[\underbrace{q_r(T_i - T_{i,s})}_{(d)} + \underbrace{\frac{\delta q_r(T_i - T_{i,s})}{\delta T_{i,s}}(T_i - T_{i,s})]}_{(e)} + \beta[\underbrace{q_s(T_{i,s})}_{(f)} + \underbrace{T_{i,s}\frac{\delta q_s(T_{i,s})}{\delta T_{i,s}}}_{(g)}] \quad (9)$$

The terms (d) and (e) have similar interpretations as (a) and (b) in case 1, the other terms can be interpreted as follows:

- Term (f): The more productive the substitute teacher, the smaller the negative effect of teacher r absence
- Term (g): This is the additional pupil-specific human capital acquired by the substitute teacher.

Overall, in case 2, the marginal effect of teacher absence will be negative if and only if:

$$\alpha[q_r(T_i - T_{i,s}) + \frac{\delta q_r(T_i - T_{i,s})}{\delta T_{i,s}}(T_i - T_{i,s})] > \beta[q_s(T_{i,s}) + T_{i,s}\frac{\delta q_s(T_{i,s})}{\delta T_{i,s}}] \quad (10)$$

In particular, equation (10) will be verified when the regular teacher is of higher quality than the substitute teacher ($q_r > q_s$) and/or when the regular teacher acquires pupil-specific human capital faster than the substitute teacher ($\delta q_r/\delta T_{i,r} > \delta q_s/\delta T_{i,s}$).

Appendix B: Main Datasets

Table 11 – Main Datasets

Name	Observation level	Period covered
OCC	teacher x assignment spell	2001 - 2015
CONG	teacher x absence spell	2001 - 2015
RELAIS	teacher x class x year	2004 - 2015
FAERE	pupil x year	2006 - 2015

Source of data: Statistical Department of the French Ministry of Education.